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User Needs

This report assesses the needs for improving our ability to track and predict the atmospheric transport of chemical, biological, or nuclear (C/B/N) atmospheric releases. These needs are defined in terms of the various communities who must respond to such threats and their counterterrorism objectives and decision-support time frames. Different user communities establish and prioritize their needs differently. By identifying end user requirements, the committee has attempted to focus on the practical application and implementation opportunities for atmospheric modeling and observational tools. The broad range of counterterrorism activities is divided into the areas of *preparedness* (which, in turn, includes *intelligence and threat assessment*, *preparedness planning*, *prevention and protection*), *response*, and *recovery and analysis*. Each of these stages places a different set of constraints and requirements on observational and modeling needs (Appendix D). Response and recovery needs are further subdivided according to the diversity of responders, their particular responsibilities, and the time scales associated with their various roles.

PREPAREDNESS

Intelligence and threat assessment involves consideration of the capabilities and attack risks linked with any potential terrorist organization, from individuals acting alone to organized groups or even hostile nation-states. Atmospheric transport modeling may contribute in several ways to this expansive effort. The historical precedent of nuclear weapons test monitoring attests to the usefulness of accurate atmospheric modeling studies as a means of retracing the transport of airborne C/B/N agents. Transport modeling may also assist in determining sensor sensitivity and sampling requirements as well as preferential locations for monitoring (either systematically for wide coverage or specifically for suspected terrorist activities). Similarly, such models may be used to assess the risk associated with any number of hypothetical threat scenarios against assumed targets.

Atmospheric transport modeling tools can be used to help determine the time, location, and magnitude of releases after they have occurred. An example of this type of

event was the tracking of radioisotopes released from the Chernobyl reactor accident. For these “hindcast” activities, particularly for cases in which extended time is available for after-the-fact analysis, existing large-scale transport models have provided useful support to the intelligence community. However, improved atmospheric dispersion modeling could contribute substantively to the design of enhanced monitoring systems, for instance, to help determine requirements for monitor location and spacing and sensor measurement sensitivities. Assessment of conjectured threats against known potential targets (such as nuclear power plants) also seems to be served satisfactorily by existing atmospheric dispersion models. For these cases, predictions of average atmospheric behavior and likely variations around mean dispersion seem adequate for general threat assessment and training purposes. However, as the need for higher temporal and spatial resolution mapping becomes greater—for example, with regard to threat assessment in urban environments and complex topographies—current transport models are not yet sufficiently useful. Furthermore, given that local-scale transport is affected by dynamic weather conditions, such models require continuous updating with observations or output from meteorological models.

Preparedness planning is a natural extension of counterterrorism threat assessment, and it complements existing emergency planning for accidental atmospheric releases of harmful agents. This particularly is the case for facilities such as petrochemical and nuclear plants that are known to be potential sites of hazardous releases and that may also be terrorist targets. Emergency responders generally have well-established plans and contingency options for reacting quickly to events involving atmospheric releases (whether accidental or purposely induced) from such pre-identified facilities. In many cases, they have trained regularly against such threats. Existing atmospheric transport models appear to be useful for site-specific planning and training needs and likewise for event-specific preparation and planning activities, such as those associated with major entertainment, sports, or other public events (e.g., the Super Bowl, a presidential inauguration).

Protection and prevention generally involve the anticipation and interdiction of suspected terrorist activity by responsible authorities before a terrorist attack occurs and, specifically, before the release of C/B/N agents into the atmosphere. Although successful interdiction implies that an atmospheric release of hazardous material has been avoided, atmospheric transport modeling can and has been used to assist in decision making for the allocation of monitoring resources and deployment of field personnel. For example, during the Salt Lake City Olympics (Appendix H), prevailing weather patterns and predicted atmospheric transport effects were used by protection forces to identify areas of heightened vulnerability or risk and, correspondingly, to help allocate available monitoring resources for maximum coverage and effectiveness. While improved transport modeling would be useful in the case of real emergency events, existing models have proven useful for satisfying these preventive resource-allocation and training needs.

RESPONSE

Once hazardous agents have been released into the atmosphere, a series of emergency response actions will occur, carried out by a variety of specialized emergency

response personnel working in concert across several overlapping time scales. Each of these users and time scales places different needs-based requirements on tools for tracking the atmospheric release. For the purpose of providing an assessment framework, actions and user needs are defined on three time scales:

1. Immediate first response (0–2 hours)
2. Early response (generally 2–12 hours)
3. Sustained response support (generally greater than 12 hours)

Response to events also is affected by knowledge of the release source term; for instance, one may have a likely known source agent (such as a nuclear power plant), an unknown source term (such as an undetermined biotoxin release), or a quasi-known source (such as a chemical explosion with visible plume but of uncertain or mixed composition).

“First responder” is a term generally used to describe the fire and rescue, medical services, and law enforcement personnel responding to an emergency over the first several hours (Appendix D). For the purposes of this study, the committee defines first responders as those individuals who are first to report and arrive at the scene of an emergency, often within minutes after the events occur. These individuals frequently will be the ones who report the emergency to local and state emergency response managers, provide an initial assessment of its nature and magnitude, and direct short-term response reaction over the first few tens of minutes of an event. Their highest priority is to protect the public and to care for the injured. Beyond whatever benefits might be derived from preparatory training exercises, there may be little opportunity for atmospheric dispersion modeling to assist in meeting first responders’ needs in the immediate aftermath of an actual terrorist attack. In contrast, real-time observations of wind, precipitation, and so forth, may play a major role in immediate decision-making.

Dispersion modelers must understand the role and capabilities of these first responders; they serve as the initial data collection interface on what has happened, often being asked to provide subjective characterization of the release events so as to best determine follow-on emergency responses over the next few hours. Their limited descriptive input may be the only information available for the first quick-look atmospheric model assessment of likely event consequences.

The early emergency response team will move into action upon receiving initial reports of an event (or a series of related events). This response team may be part of larger emergency management teams that are state, county, or municipality based, depending on the event location. Emergency response protocol establishes the official primacy of local authorities in dealing with such emergencies, although state, regional, and federal resources may be actively engaged in providing various degrees of supplemental support. The experience and training of these early emergency response teams is especially crucial during these chaotic first few hours following a release. In larger population centers, a member of the emergency response team likely will have some level of experience and capability in using very simple transport modeling tools (such as CAMEO/ALOHA [Computer-Aided Management of Emergency Operations—Areal Locations of Hazardous Atmospheres], discussed in Chapter 4). In more rural or

less prepared locales or for the use of more sophisticated models, emergency response teams may need more complete advisory support from a national or regional atmospheric modeling center.

The initial response plan over the first several hours of an event typically will include execution of a quick-look atmospheric transport model prediction. This model may have very limited access to real-time atmospheric data and information about the hazard source (in terms of injection dynamics, aerosol size and composition, and potential lethal dosage¹). Over the next few hours, as additional real-time data and source term information become available, modeling predictions will become increasingly accurate and specific.

It is essential that the atmospheric modeling results support the decision-making needs of this early responder community (Appendix D). Within the first few tens of minutes to several hours, emergency managers are working to resolve several critical issues, including a quick decision on the type of personal protective equipment and devices to be used to ensure the safety of the on-site responders (police, fire, medical personnel) and a decision as to evacuate or to shelter-in-place civilian populations in event impact areas. Over the next several to 12 hours, the emergency response team will be working to refine these evaluations and predictions, to assess the downwind impact zone in accordance with atmospheric transport and dispersion models so as to provide timely warning to threatened downwind populations, and to provide support for recovery efforts involving response personnel entering or re-entering affected areas. (Box 2.1.)

The time beyond roughly 12 hours following an event typically represents the transition period from crisis management to some degree of sustained managed response and the beginning of recovery activities. Of course, for long-lived chemical, biological, or nuclear releases, the response and recovery activities overlap significantly. As transport and dispersion models are supported by a more complete database of detailed atmo-

BOX 2.1

Secondary Users of Dispersion Information

In addition to the various types of first responders identified, there are a host of potential “secondary” users of information about atmospheric dispersion of hazardous agents. These may include public health officials, state and regional poison centers, hospitals, and non-governmental organizations that provide care and shelter for affected populations (Appendix D). There also may be numerous inquiries from the news media, political officials, and members of the legal and judicial communities (e.g., regarding Federal Bureau of Investigation forensic investigations). In most situations, it is best for those involved in atmospheric observational or modeling support to defer direct interactions with these secondary user groups to the established emergency response organizations.

¹ Dosage is the dose expressed as a function of time and the organism being dosed; for example, it can be expressed as milligrams per kilogram of body weight per day ($\text{mg kg}^{-1} \text{day}^{-1}$).

spheric observations and contaminant monitoring measurements, the response tasks also become correspondingly precise in terms of determining requirements for personal protective equipment, exposure² estimates across finer spatial resolutions, and consequence assessment.

Especially during this period, the modeling support team must be familiar with non-technical aspects of the emergency management team's decision-making process. The decision makers not only need access to the best atmospheric transport predictions, but they also require reasonable estimates of the variability and confidence levels of results. They typically must reach some balance between safety concerns under a worst-case lethality scenario and the expense and other consequences accompanying over-reaction to such a scenario. In addition, while model output generally can be no better than data input, even the most sophisticated emergency response team members caution that models requiring input data from the end user that the user does not understand or cannot immediately provide will result in the model's being quickly discarded. Model providers must work diligently to assume the perspective of the end user by always asking, "What is needed, and how much is enough?" They also must recognize that the emergency responder often will have to reach a decision based upon whatever incomplete or imprecise information is available at the time. Transport modeling must be designed to provide the best support available even under the most difficult and limiting circumstances.

Finally, the emergency response team does not enjoy the luxury of a posteriori statistical analysis and comparison of differences accompanying competing atmospheric models. They need definitive support—without excessive complexity, caveat, or confusion—to directly address the decisions they must make, on the timetable on which they must make them. The burden of interfacing the atmospheric transport models to the decision-making needs of the emergency response team generally must fall upon the modeling community. A regular series of "tabletop," functional, and full-scale event simulation exercises (Box 2.2), bringing together emergency response teams and members of the atmospheric modeling and observational communities, would greatly benefit all parties involved and facilitate the development of a common set of data interface and decision support protocols.

The emergency responders who participated in the workshop uniformly agreed that in real emergency events, the atmospheric modeling community should speak with a single voice. There is general dissatisfaction with the large number of seemingly competitive atmospheric transport models and services now supported by various agencies. Conversely, there is wide agreement on the value of having a single point of contact (preferably reachable through a 1-800 phone number) that can provide a clearinghouse of information about the available observational and modeling support and immediately connect first responders and emergency managers to the appropriate centers of technical

² Exposure is the concentration, amount, or intensity of a particular agent that reaches the target population, usually expressed in numerical terms of substance concentration, duration, and frequency (for chemical agents and micro-organisms) or intensity (for physical agents such as radiation).

BOX 2.2

Tabletop Exercises

Regular day-to-day interactions among the relevant players in an emergency response action (e.g., first responders, dispersion modelers, meteorologists) are necessary to ensure an effective working relationship. One particularly useful form of interaction is the tabletop exercise—a common method of training in the emergency management community, wherein participants plan and discuss responses to a given emergency scenario and sequence of events that may unfold during the course of that response. Tabletop exercises provide an opportunity to familiarize personnel with emergency response plans and to identify the roles and responsibilities of various individuals and organizations under those plans. Such exercises also provide a useful forum for allowing all of the different organizations involved in the response to a major incident to get to know each other and to work together. Tabletop exercises provide an effective means to educate personnel and practice emergency response without committing large amounts of time and resources. However, the need for at least occasional full-scale field exercises will remain, as they are essential for testing the appropriateness and execution of established procedures, the operability of models, and the interactions among all the various players involved in an emergency response action.

expertise. Of course, the usefulness of such a system will first require a comprehensive understanding of customer needs and the capabilities of various existing dispersion modeling centers. Such a resource may be especially valuable in smaller cities, towns, and rural areas, where first responders (who are often volunteer firefighters) may have little information about how to obtain immediate assistance.

Additionally, because of conflicting concerns over liability for decisions made and actions undertaken during the difficult first few hours following a terrorist attack, many in the responder community urge that atmospheric dispersion modeling and prediction be managed as a federal service.

As discussed in greater detail in Chapter 4, most models predict the average dispersion (over a large number of realizations of the given situation) and not the event-to-event variability about that average. As a result, even a good atmospheric transport model may have single-event errors of more than a factor of ten. In determining evacuation zones based upon estimates of lethality dosage, fluctuations of this magnitude represent substantial human health risks. It is important that atmospheric models applied to individual atmospheric releases provide predictions with clearly stated uncertainties.

There is an opportunity to improve the overall understanding of atmospheric transport and dispersion modeling by advancing research in this field and by synergistically combining the different techniques and approaches, as described later in this report. The subtleties of choosing among models, and determining how they are to work together under changing atmospheric conditions and output needs, must remain the chal-

lenge of a nationally coordinated effort and not be left as a responsibility of emergency response managers in the field. These end users have requested modeling outputs that offer simplicity, repeatability, scalability, and timeliness. With appropriate attention, the committee believes atmospheric transport and dispersion modeling can meet these needs and substantially enhance our national emergency response capability.

RECOVERY AND ANALYSIS

There is no specific timetable that establishes when recovery from a harmful atmospheric release begins. Because of the nature of transport, event recovery may be well underway in areas initially affected by the release as the hazardous agents reach new locations downwind. Atmospheric transport models should provide accurate prediction, warning, and exposure assessments for these later-time concerns (Box 2.3).

During the recovery period, health care workers will become much more active in reaching and caring for the injured. Atmospheric modeling predictions of exposure expectations will help the health care community assess the size of the needed response and the accumulation and allocation of necessary resources to deal with the events. Also, during the necessary triage of incapacitated and ambulatory injured, model predictions of exposure may influence the interpretation of symptoms and treatment modalities.

Emergency response workers will continue to monitor contaminant exposure levels and confirm when an area is safe to reenter, prescribing personal protective equipment as a function of exposure risk. Modeling efforts may prove especially valuable in highlighting possible geographic or structural areas capable of capturing and maintaining dangerous concentration levels of persistent hazardous agents. At some point, those who have been evacuated from their communities will be allowed to return home. The timing of such actions will depend in large part on the decontamination needs of the built environment, including likely contaminant collection sites such as storm drains, sanitary sewers, and building basements. In some cases, long-term environmental monitoring and restoration of natural lands, plants and animals, and waterways may become necessary.

BOX 2.3 Examples of Model Application to Post-event Analysis

Several examples discussed at the workshop illustrated how dispersion models can contribute to post-event exposure assessments over a wide range of spatial scales. For instance, following the Chernobyl nuclear accident, regional- and global-scale transport models were used to assess what locations and populations may have been exposed to radioactive fallout (Appendix G). Following the attacks on the World Trade Center, urban-scale dispersion models were used to assess what neighborhoods were exposed to the plumes of smoke emanating from the fires (Appendix F). Variable-scale dispersion modeling studies were carried out after the Persian Gulf War to predict dosage probability distributions (Appendix E).

KEY FINDINGS AND RECOMMENDATIONS

Atmospheric observations and dispersion models must interface seamlessly with the needs of emergency responders. Emergency response managers would benefit from training that conveys the strengths and weaknesses of existing observational and dispersion modeling tools and the situations under which various types of tools perform best. Conversely, dispersion modelers and meteorologists would benefit from learning how nowcasts and forecasts are used in emergency response situations. **“Tabletop” (i.e., roundtable discussion and planning) event simulation exercises should be convened regularly to bring together emergency response teams and members of the atmospheric modeling and observational communities to help establish and exercise a common set of data interface and decision support protocols.**

Emergency responders face a confusing array of seemingly competitive atmospheric transport model systems supported by various agencies, and in many cases, they do not have a clear understanding of where to turn for immediate assistance. **A single federal point of contact should be established (such as a 1-800 phone number) that could be used to connect emergency responders across the country to appropriate dispersion modeling centers for immediate assistance.**

Emergency managers need a realistic understanding of the bounds on the uncertainties of dispersion model predictions. Dispersion model predictions of the concentrations for a given release need to be accompanied by a prediction of the event-to-event variability in that situation. **Dispersion modelers should use ensemble modeling or other approaches that quantify not only the average downwind concentration distribution in a given situation, which is interpretable as the most likely outcome, but also the event-to-event variability to be expected. The specific formats of the information presented should be developed in close collaboration with users of this information.**